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Mass Luminosity Ratio of Nearby Stars and its Relation to Baryonic Dark Matter Problem

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Abstract. In view of the recent report on the discovery of low mass halo stars for the candidates of MACHOs, a calculation has been made for the possible enhancement of M/L ratio for populations of stars of varying mass domains taking the input data from the latest present day mass function (PDMF) of stars. It is seen that there is good scope for explaining dark matter problem where the dark matter is mostly in the form of low mass stars.

Key words: Baryonic dark matter—present day mass function and M/L ratio.

1. Introduction

It is seen that in the solar neighbourhood of the disc the mass to luminosity ratio in units of $M_\odot/L_\odot$ is fairly low, 0(2–3), but on the whole scale of the Galaxy there is a substantial contribution to mass by partially visible halo and therefore the mass to light ratio of the galaxy as a whole increases to a large extent ~ 10 or more. It is also observed that when we go to the larger scales of length, like including several galaxies in the cluster of galaxies, this problem of mass to light ratio becomes more acute, mainly values, that is, the ratio shoots up to ~ 30–100. When we consider superclusters of galaxies the M/L ratio is very large ~ 200–1000. This problem is canonically known as the dark matter problem.

Obviously for the sun the M/L ratio is defined to be as unity and in the solar neighbourhood more than 99% of stars are slightly less massive than the sun. Hence the stellar M/L ratio is not very much different from unity. But the fact remains that on the higher scales of distance the M/L ratio goes up.

In the present work, a study has been made using the latest input of the basic stellar parameters and the local spatial distribution of stars, namely the mass function of stars. We are trying to determine how M/L ratio could be affected by the imposition of a cut-off at the lower or the upper end of the mass function.

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2. Methodology and the present work

The test input for this study consists as follows:

(i) Mass luminosity calibration using Anderson data has already been obtained by Srivastava *et al.* (1993).
(ii) For the construction of the PDMF and the IMF luminosity, function of the local stars given in Basu's thesis (1993) is used, and
(iii) M_v, that is, the visual magnitude and the bolometric correction to be used for the analysis were taken from Srivastava *et al.* (1993).

First we constructed PDMF (ϕ_{ms}log m) from the luminosity function of the stars and corrected for the multiple stellar component in the scheme presented by Basu & Rana (1992). We are more concerned about PDMF than IMF, even though we have calculated IMF in order to find out the average star formation rate in the solar neighbourhood.

We present the plot fox the luminosity function. This is, by definition, the number of stars per unit volume (pc) per unit interval of the visual magnitude M_v running from 17th magnitude on the fainter side to about – 6.5 on the brighter side. We calculate $\langle M/L \rangle$ as

$$\left\langle \frac{M}{L_v} \right\rangle = \frac{\int_{\log m_l}^{\log m_u} [m/L_v]\,\phi_{ms}(\log m)\,\mathrm{d}\log m}{\int_{\log m_l}^{\log m_u} \phi_{ms}(\log m)\,\mathrm{d}\log m};\ \left\langle \frac{M}{L} \right\rangle = \frac{\int_{\log m_l}^{\log m_u} [m/L]\,\phi_{ms}(\log m)\,\mathrm{d}\log m}{\int_{\log m_l}^{\log m_u} \phi_{ms}(\log m)\,\mathrm{d}\log m}$$

We vary the lower limit (log m_l) keeping the upper limit (log m_u) fixed and see how the $\langle M/L_v \rangle$ is varying. Next we varied log m_u keeping log m_i fixed. The result is shown in Table 1 and a corresponding plot in Fig. 1, where $\langle M/L_v \rangle$ is given varying with

Table 1. *M/L* ratios for varying upper and lower limits of stellar mass in the PDMF (all in solar units).

Log m	Log(M/L_v) for fixed lowermost limit of log m	Log(M/L) for fixed lowermost limit of log m	Log(M/L_v) for fixed uppermost limit of log m	Log(M/L) for fixed uppermost limit of log m
– 1.2	4.62	3.62	– 2.45	– 4.45
– 1.0	3.51	2.07	– 2.52	– 4.35
– 0.8	2.66	1.76	– 2.53	– 4.30
– 0.6	2.45	1.43	– 2.46	– 3.94
– 0.4	2.05	1.24	– 2.14	– 3.39
– 0.2	1.38	0.99	– 1.64	– 2.56
0.0	0.74	0.60	– 0.90	– 1.50
0.2	0.49	0.40	– 0.38	– 0.75
0.4	0.42	0.37	– 0.13	– 0.48
0.6	0.40	0.28	0.00	– 0.35
0.8	0.39	0.23	0.08	– 0.27
1.0	0.38	0.17	0.14	– 0.21
1.2	0.37	0.12	0.21	– 0.15
1.4	0.37	0.08	0.27	– 0.13
1.6	0.37	0.04	0.31	– 0.11
1.8	0.36	0.02	0.32	– 0.10
2.0	0.36	– 0.08	0.36	– 0.08

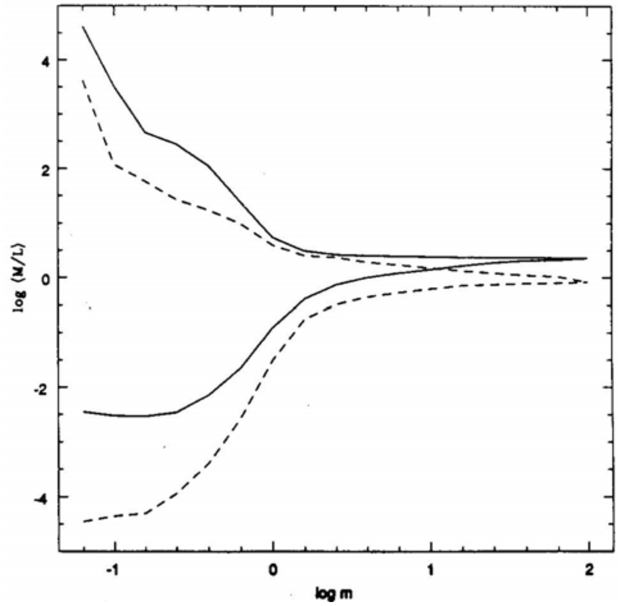

Figure 1. A plot for the ratios $\langle M/L_v \rangle$ and $\langle M/L \rangle$ vs increasing upper limit of stellar mass keeping the lower limit at the lowest end and vs decreasing lower limit of stellar mass keeping upper limit at the uppermost end, and suitably averaged over the observed PDMF of the main, sequence stars in the solar neighbourhood. Solid line corresponds to log $\langle M/L_v \rangle$ vs log m and the dashed line for log $\langle M/L \rangle$ vs log m. Only the upper sections of these two curves are relevant for the discussion of the present work.

the mass limits. After correcting for the bolometric correction (BC) we obtain true luminosity of each star and perform the same exercise once again. The idea has been to see whether large M/L ratio can be obtained at all, by introducing a cut-off at a different level of absolute magnitude or mass, that is, equivalently the mass of the star. It is always suspected that the halo of galaxy contains subluminous, subsolar stars of late spectral type, say K, or M dwarfs. This work is to test the viability of such a hypothesis.

3. Discussion and conclusion

It is seen that if any system of stars has got a large population of very low mass stars, the effective M/L ratio can go up to an order of 10^3 provided the average mass of the low mass stars is about 0.1 $M_\odot$ or so. If it so happens that under conditions of low metallicity, low turbulence and low magnetic field, the star formation, for example in the halo, had taken place with a substantial peak at low mass, particularly around 0.1 $M_\odot$, then the M/L ratio for the solar neighbourhood can remain at about 2.5 or lower while in the halo or the older populations could have a substantially higher M/L ratio due to stars only. Already direct indications for MACHOs have been reported in the recent TAUP '93 meeting at L'Aquila, Italy, September 22 1993, on behalf of EROS collaboration (A. Milsztajn *et al.*) and of Barkeley Australia collaboration (D. Spergel *et al*.), for a possible large population of low mass stars (about 0.1 $M_\odot$) in the halo of the Galaxy. The present work justifies such a case as a viable one from the latest form of the present day mass function obtained by Basu & Rana (1992) and Basu (1993). As we move away from the plane of the disc, massive stars gradually drop out from the high mass end, and by the time we reach the value of <0.5 $M_\odot$in the halo, $\langle M/L_v \rangle$ becomes as high as ~ 100, even if the general form of the PDMF over the relevant range of mass is taken to be universal.

It should also be noted that the finite age of the disc brings in a natural cut-off in stellar mass at about 0.95 $M_\odot$ in the mass function, but we have gone further below this limit assuming halo stars had its own Wielen type of dip in mass function in the domain of low mass stars; it does not surely affect our result even if there existed another peak in the mass function on the high mass side for the halo stars.

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